



## Air Pollution Control Technology Fact Sheet

**Name of Technology:** Catalytic Incinerator

This type of incinerator is also referred to as a catalytic oxidizer, or catalytic reactor.

**Type of Technology:** Destruction by oxidation.

**Applicable Pollutants:**

Volatile organic compounds (VOC) and many types of particulate matter (PM). In the past, catalytic incinerators were not recommended as a control device for PM, since the PM, unless removed prior to incineration, often coated (or "blinded") the catalyst so that the catalyst's active sites were prevented from aiding in the oxidation of pollutants in the gas stream (EPA, 1998). Examples are gases containing chlorine, sulfur, and other atoms, such as phosphorous, bismuth, lead, arsenic, antimony, mercury, iron oxide, tin, and zinc that may deactivate the supported noble metal catalysts (EPA, 1991).

However, catalysts have been recently developed that can tolerate almost any compound. Most of these catalysts are single or mixed metal oxides, often supported by a mechanically strong carrier such as various types of alumina. Catalysts such as chromia/alumina, cobalt oxide, and copper oxide/manganese oxide have been used for oxidation of gases containing chlorinated compounds. Platinum-based catalysts are active for oxidation of sulfur containing VOC, although they are rapidly deactivated by the presence of chlorine (EPA, 1996a).

**Achievable Emission Limits/Reductions:**

VOC destruction efficiency is dependent upon VOC composition and concentration, operating temperature, oxygen concentration, catalyst characteristics, and space velocity. Space velocity is commonly defined as the volumetric flow of gas entering the catalyst bed chamber divided by the volume of the catalyst bed. The relationship between space velocity and VOC destruction efficiency is strongly influenced by catalyst operating temperature. As space velocity increases, VOC destruction efficiency decreases, and as temperature increases, VOC destruction efficiency increases. As an example, a catalytic unit operating at about 450°C (840°F) with a catalyst bed volume of 0.014 to 0.057 cubic meter ( $m^3$ ) (0.5 to 2 cubic feet ( $ft^3$ )) per 0.47 standard cubic meters per second ( $sm^3/sec$ ) (1,000 standard cubic feet per minute (scfm)) of offgas passing through the device can achieve 95 percent VOC destruction efficiency (EPA, 1992). Higher destruction efficiencies of (98 - 99 percent) are achievable, but require larger catalyst volumes and/or higher temperatures, and are usually designed on a site-specific basis (EPA, 1991).

In EPA's 1990 National Inventory, incinerators as a group, including catalytic incinerators, were reported as being used as control devices for PM and were reported as achieving 25 - 99% control efficiency of  $PM_{10}$  at point source facilities (EPA, 1998). Table 1 presents a breakdown of the  $PM_{10}$  control efficiency ranges by industry where catalytic incinerators have been reported (EPA, 1996b). The VOC control efficiency reported for these devices ranged from 0 to 99.9%, however, it is assumed that reports of higher efficiencies (greater than 99%) are attributable to thermal incinerators. These ranges of control efficiencies are large because they include facilities that do not have VOC emissions and control only PM, as well as facilities which have low PM emissions and are primarily concerned with controlling VOC (EPA, 1998).

**Table 1. PM<sub>10</sub> Destruction Efficiencies for Catalytic Incinerators and Catalytic Incinerators with Heat Exchanger by Industry (EPA, 1996b)**

<b>Industry/Types of Sources</b>	<b>PM<sub>10</sub> Control Efficiency (%)</b>
<b>Petroleum and Coal Products</b> asphalt roofing processes (blowing, felt saturation); mineral calcining; petroleum refinery processes (asphalt blowing, catalytic cracking, coke calcining, sludge converter); sulfur manufacturing	25 - 99.9
<b>Chemical and Allied Products</b> carbon black manufacturing (mfg); charcoal mfg; liquid waste disposal; miscellaneous chemical mfg processes; pesticide mfg; phthalic anhydride mfg (xylene oxidation); plastics/synthetic organic fiber mfg; solid waste incineration (industrial)	50 - 99.9
<b>Primary Metals Industries</b> by-product coke processes (coal unloading, oven charging and pushing, quenching); gray iron cupola and other miscellaneous processes; secondary aluminum processes (burning/drying, smelting furnace); secondary copper processes (scrap drying, scrap cupola, and miscellaneous processes); steel foundry miscellaneous processes; surface coating oven	70 - 99.9
<b>Electronic and Other Electric Equipment</b> chemical mfg miscellaneous processes; electrical equipment bake furnace; fixed roof tank; mineral production miscellaneous processes; secondary aluminum roll/draw extruding; solid waste incineration (industrial)	70 - 99.9
<b>Electric, Gas, and Sanitary Services</b> internal combustion engines; solid waste incineration (industrial, commercial/ institutional)	90 - 98
<b>Stone, Clay, and Glass Products</b> barium processing kiln; coal cleaning thermal dryer; fabricated plastics machinery; wool fiberglass mfg	50 - 95
<b>Mining</b> asphalt concrete rotary dryer; organic chemical air oxidation units, sulfur production	70 - 99.6
<b>Educational Services</b> solid waste incineration (commercial/ institutional)	80
<b>Paper and Allied Products</b> boiler	95
<b>Printing and Publishing</b> surface coating dryer; fugitives	95

**Applicable Source Type:** Point

**Typical Industrial Applications:**

Catalytic incinerators can be used to reduce emissions from a variety of stationary sources. Solvent evaporation processes associated with surface coating and printing operations are a major source of VOC emissions, and catalytic incineration is widely used by many industries in this category. Catalytic incinerators are also used to control emissions from the following (EPA, 1992):

- Varnish cookers;
- Foundry core ovens;
- Filter paper processing ovens;
- Plywood veneer dryers;
- Gasoline bulk loading stations;
- Process vents in the synthetic organic chemical manufacturing industry (SOCMI);
- Rubber products and polymer manufacturing; and
- Polyethylene, polystyrene, and polyester resin manufacturing.

Catalytic oxidation is most suited to systems with lower exhaust volumes, when there is little variation in the type and concentration of VOC, and where catalyst poisons or other fouling contaminants such as silicone, sulfur, heavy hydrocarbons and particulates are not present.

**Emission Stream Characteristics:**

- a. **Air Flow:** Typical gas flow rates for packaged catalytic incinerators are 0.33 to 24 sm<sup>3</sup>/sec (700 to 50,000 scfm) (EPA, 1996a).
- b. **Temperature:** Catalysts in catalytic incinerators cause the oxidizing reaction to occur at a lower temperature than is required for thermal ignition. Waste gas is heated by auxiliary burners to approximately 320°C to 430°C (600°F to 800°F) before entering the catalyst bed (AWMA, 1992). The maximum design exhaust temperature of the catalyst is typically 540° - 675°C (1000° - 1250°F).
- c. **Pollutant Loading:** Catalytic incinerators can and have been used effectively at very low inlet loadings; down to 1 part per million by volume (ppmv) or less (EPA, 1995). As with thermal and recuperative incinerators, for safety considerations, the maximum concentration of the organics in the waste gas must be substantially below the lower flammable level (lower explosive limit, or LEL) of the specific compound being controlled. As a rule, a safety factor of four (i.e., 25% of the LEL) is used (EPA, 1991, AWMA, 1992). The waste gas may be diluted with ambient air, if necessary, to lower the concentration.
- d. **Other Considerations:** Characteristics of the inlet stream should be evaluated in detail, because of the sensitivity of catalytic incinerators to VOC inlet stream flow conditions, which may cause catalyst deactivation (EPA, 1992).

**Emission Stream Pretreatment Requirements:**

Typically, if design conditions are satisfied no pretreatment is required, however, in some cases, PM removal may be necessary before the waste gas enters the incinerator.

## Cost Information:

The following are cost ranges (expressed in 2002 dollars) for packaged catalytic incinerators of conventional design with fixed beds under typical operating conditions, developed using EPA cost-estimating spread sheets (EPA, 1996a) and referenced to the volumetric flow rate of the waste stream treated. The costs do not include costs for a post-oxidation acid gas treatment system. Costs can be substantially higher than the ranges shown when used for low-VOC concentration streams (less than around 100 ppmv). As a rule, smaller units controlling a low concentration waste stream will be much more expensive (per unit volumetric flow rate) than a large unit cleaning a high pollutant load flow. Operation and Maintenance (O & M) Costs, Annualized Cost, and Cost Effectiveness are dominated by the cost of supplemental fuel required.

- a. **Capital Cost:** \$47,000 to \$191,000 per  $\text{sm}^3/\text{sec}$  (\$22 to \$90 per scfm)
- b. **O & M Cost:** \$8,500 to \$53,000 per  $\text{sm}^3/\text{sec}$  (\$4 to \$25 per scfm), annually
- c. **Annualized Cost:** \$17,000 to \$106,000 per  $\text{sm}^3/\text{sec}$  (\$8 to \$50 per scfm), annually
- d. **Cost Effectiveness:** \$105 to \$5,500 per metric ton (\$100 to \$5,000 per short ton), annualized cost per ton per year of pollutant controlled. However, when used to treat very low concentrations of toxic air pollutants (less than 100 ppmv), the cost per ton removed may be many thousands of dollars, because only a small amount of pollutant is being destroyed.

## Theory of Operation:

Catalytic incinerators operate very similar to thermal/recuperative incinerators, with the primary difference that the gas, after passing through the flame area, passes through a catalyst bed. The catalyst has the effect of increasing the oxidation reaction rate, enabling conversion at lower reaction temperatures than in thermal incinerator units. Catalysts, therefore, also allow for smaller incinerator size. Catalysts typically used for VOC incineration include platinum and palladium. Other formulations include metal oxides, which are used for gas streams containing chlorinated compounds (EPA, 1998).

In a catalytic incinerator, the gas stream is introduced into a mixing chamber where it is also heated. The waste gas usually passes through a recuperative heat exchanger where it is preheated by post combustion gas. The heated gas then passes through the catalyst bed. Oxygen and VOC migrate to the catalyst surface by gas diffusion and are adsorbed onto the catalyst active sites on the surface of the catalyst where oxidation then occurs. The oxidation reaction products are then desorbed from the active sites by the gas and transferred by diffusion back into the gas stream (EPA, 1998).

Particulate matter can rapidly coat the catalyst so that the catalyst active sites are prevented from aiding in the oxidation of pollutants in the gas stream. This effect of PM on the catalyst is called blinding, and will deactivate the catalyst over time. Because essentially all the active surface of the catalyst is contained in relatively small pores, the PM need not be large to blind the catalyst. No general guidelines exist as to the PM concentration and size that can be tolerated by catalysts, because the pore size and volume of catalysts vary widely. This information is likely to be available from the catalyst manufacturers (EPA, 1996a).

The method of contacting the VOC-containing stream with the catalyst serves to distinguish catalytic incineration systems. Both fixed-bed and fluid-bed systems are used.

Fixed-bed catalytic incinerators may use a monolith catalyst or a packed-bed catalyst (EPA, 1996a):

**Monolith Catalyst Incinerators** - The most widespread method of contacting the VOC-containing stream with the catalyst is the catalyst monolith. In this scheme the catalyst is a porous solid block containing parallel, non-intersecting channels aligned in the direction of the gas flow. Monoliths offer the

advantages of minimal attrition due to thermal expansion/contraction during startup/shutdown and low overall pressure drop.

**Packed-Bed Catalytic Incinerators** - A second contacting scheme is a simple packed-bed in which catalyst particles are supported either in a tube or in shallow trays through which the gases pass. This scheme is not in widespread use due to its inherently high pressure drop, compared to a monolith, and the breaking of catalyst particles due to thermal expansion when the confined catalyst bed is heated/cooled during startup/shutdown. However, the tray type arrangement of a packed-bed scheme, where the catalyst is pelletized, is used by several industries (e.g., heat-set web-offset printing). Pelletized catalyst is advantageous where large amounts of such contaminants as phosphorous or silicon compounds are present.

Fluid-bed catalytic incinerators have the advantage of very high mass transfer rates, although the overall pressure drop is somewhat higher than for a monolith. An additional advantage of fluid-beds is a high bed-side heat transfer as compared to a normal gas heat transfer coefficient. This higher heat transfer rate to heat transfer tubes immersed in the bed allows higher heat release rates per unit volume of gas processed and, therefore, may allow waste gas with higher heating values to be processed without exceeding maximum permissible temperatures in the catalyst bed. In these reactors the gas phase temperature rise from gas inlet to gas outlet is low, depending on the extent of heat transfer through imbedded heat transfer surfaces. The catalyst temperatures depend on the rate of reaction occurring at the catalyst surface and the rate of heat exchange between the catalyst and imbedded heat transfer surfaces.

As a general rule, fluid-bed systems are more tolerant of PM in the gas stream than either fixed-bed or monolithic catalysts. This is due to the constant abrasion of the fluidized catalyst pellets, which helps remove PM from the exterior of the catalysts in a continuous manner. A disadvantage of a fluid-bed is the gradual loss of catalyst by attrition. However, attrition-resistant catalysts have been developed to overcome this disadvantage.

#### **Advantages:**

Advantages of catalytic incinerators over other types of incinerators include (AWMA, 1992; Cooper and Alley, 1994):

- b. Lower fuel requirements;
- c. Lower operating temperatures;
- d. Little or no insulation requirements;
- e. Reduced fire hazards;
- f. Reduced flashback problems; and
- g. Less volume/size required.

#### **Disadvantages:**

Disadvantages of catalytic incinerators include (AWMA, 1992):

- a. High initial cost;
- b. Catalyst poisoning is possible;
- c. Particulate often must first be removed; and
- d. Spent catalyst that cannot be regenerated may need to be disposed.

#### **Other Considerations:**

Catalytic incinerators offer many advantages for the appropriate application. However, selection of a catalytic incinerator should be considered carefully, as the sensitivity of catalytic incinerators to VOC inlet

stream flow conditions and catalyst deactivation limit their applicability for many industrial processes (EPA, 1992).

#### **References:**

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